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Improving the Accuracy of the VO2 max Prediction Obtained from Submaxial YMCA Testing

Lindsay Parson
Western Kentucky University

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Improving the Accuracy of the VO₂ max Prediction Obtained from Submaximal YMCA Testing

A Thesis
Presented to
The Faculty of the Department of Physical Education and Recreation
Western Kentucky University
Bowling Green, Kentucky

In Partial Fulfillment
Of The Requirements for the Degree
Master of Science in Physical Education

By
Lindsay Elizabeth Parson

December 2004

(Signature Page)

Improving the Accuracy of the VO₂ max Prediction Obtained from Submaximal YMCA
Testing

Date Recommended 8-5-04

A. M. Lee
Director of Thesis

John R. McCall
Shad R. Crews

Peter S. Lewis
Karl L. ...

Elmer Gray 1-04-05
Dean, Graduate Studies and Research Date

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Lindsay Elizabeth Parson

December 2004

40 pages

Directed by: Dr. Matt Green

Department of Physical Education and Recreation

Western Kentucky University

Maximal oxygen uptake (VO_2 max) is the best criterion measure for aerobic fitness and the prescription of exercise intensity for programs designed to enhance cardiorespiratory fitness. There are two ways of obtaining VO_2 max: maximal tests, which require subjects to exercise to the point of volitional exhaustion and provide the most accurate measure; and submaximal tests, which are less physically strenuous but have lower accuracy. A popular submaximal protocol is the YMCA bike test. Steady state heart rate (HR) is measured at multiple submaximal workloads and extrapolated to the subject's estimated maximal HR ($220 - \text{age}$). The VO_2 corresponding to the estimated maximal HR is accepted as the estimated VO_2 max. The accuracy of this submaximal testing protocol effects the ability to estimate a subject's actual aerobic capacity. To help better investigate the YMCA protocol, submaximal measures (HR, VO_2) were utilized at specific workloads in an attempt to improve the accuracy of the prediction. The standard YMCA protocol was completed and then extended to actual maximal exertion. Submaximal measures (HR, VO_2 , etc.) were used to develop a regression equation predicting VO_2 max. T-tests were used to compare VO_2 data between protocols.

Multiple regression analyses were performed to generate regression equations to enhance the accuracy of VO_2 max estimations from the YMCA submaximal protocol. Results were considered to have no significant difference in the new regression equation and the actual measured VO_2 max. Because submaximal measures (HR, VO_2) could not be utilized to improve the accuracy of the prediction of the YMCA protocol, the original purpose was deemphasized and redirected. Considering the apparent utility of anthropometric measures in estimating VO_2 max, this study sought to improve the accuracy of the YMCA protocol by adding anthropometric measures (BMI, Skinfolds) to develop two separate regression models. Results were significantly different ($p \leq 0.05$) between Measured VO_2 (MVO_2) and VO_2 estimated from the YMCA protocol (YVO_2). Additionally, results were significantly different ($p = 0.003$) between the Houston non-exercise test and MVO_2 . In conclusion, although a significant correlation resulted between MVO_2 and YVO_2 , it was not stronger than other submaximal estimations. Also, it was not a strong predictor because of a significant difference between the Houston non-exercise test and MVO_2 . Therefore, by adding BMI and Skinfolds to the popular YMCA formula, r -values were increased ($r = 0.817$ and $r = 0.822$) and can therefore better estimate a subject's VO_2 max versus solely using graphic plots of steady state HR responses at protocol-determined workloads.

Chapter 1

Introduction

Maximal oxygen uptake ($\text{VO}_2 \text{ max}$) provides the best criterion measure for aerobic fitness and prescription of exercise intensity in programs designed to enhance cardiorespiratory fitness. $\text{VO}_2 \text{ max}$ is related to the functional capacity of the heart (ACSM 2000) and the aerobic capacity of the active musculature (Maud and Foster 1995). $\text{VO}_2 \text{ max}$ can be estimated from performance on various standardized submaximal protocols including cycle, treadmill, and arm ergometers. $\text{VO}_2 \text{ max}$ can also be measured directly; however, such measurements require an intense effort, sophisticated equipment, and trained staff.

Maximal tests require subjects to exercise to the point of volitional exhaustion and, because of the risks associated with intense physical exertion, may require the presence of a physician. Maximal exercise with direct measures of VO_2 permits a more accurate determination of $\text{VO}_2 \text{ max}$ compared to estimations from submaximal protocols. This direct measurement results in a better foundation for prescribing exercise intensity. In order for a subject to participate in a maximal exercise test, he/she should first go through a series of screening procedures and be cleared using such professional guidelines as the American College of Sports Medicine (ACSM 2000). It is suggested that only “low risk” individuals participate without the consent or presence of a physician. Males must be less than 45 years old and females must be less than 55 years old. While these and other professional guidelines are established to help ensure safety of testing, they may act as a barrier for conducting maximal exercise tests to determine $\text{VO}_2 \text{ max}$ in certain populations.

In addition to reflecting aerobic fitness level, VO_2 max often provides the basis for exercise intensity prescription. Using percentages of the VO_2 max, a range can be established to guide individuals in regulating their intensity during exercise. While this maximal testing increases precision versus estimations, it is not feasible or safe for everyone to participate in a maximal exercise test. In older populations, and situations in which large groups are to be tested, submaximal tests are more practical for estimating cardiorespiratory fitness. Submaximal tests permit larger populations and those at increased risk to participate without assuming excessive risks. Also, compared to maximal tests, submaximal tests are physically less strenuous and thus result in less discomfort and pain experienced by subjects. However, when using submaximal protocols the accuracy of determining VO_2 max is impaired, potentially hindering the prescription and regulation of intensity. Although the accuracy may be impaired, submaximal protocols are more ideal for the general population because of safety concerns (ACSM, 2000) and are beneficial when time or equipment is limited (Maud and Foster 1995).

A variety of submaximal protocols exist. These protocols vary in accuracy of the VO_2 max estimation they provide. Correlations of estimated VO_2 max with measured VO_2 max for some examples include Astrand-Ryhming Test ($r=0.80$) (Astrand and Ryhming, 1954), Queens College Step Test ($r=0.92$) (McArdle et. al., 1972), Siconolfi Step Test ($r=0.92$) (Siconolfi et. al., 1985), and One-Mile Walk Test ($r=0.88$) (Kline et. al., 1987). Another possibility for estimating VO_2 max is the non-exercise estimation (Jackson et. al., 1990). The procedure requires subjects to enter personal data (age and percent body fat or body mass index) as well as an estimation of current physical activity

level to predict VO_2 max. One equation uses Body Mass Index (BMI) while the other uses estimated percent body fat. The correlations for the two non-exercise equations are 0.81 and 0.78, respectively. In comparing the correlations for sub-maximal protocols and the non-exercise equation, it appears that VO_2 max can be predicted without having submaximal test data almost as accurately as with submaximal test data.

The basic aim of submaximal exercise testing is to determine the heart rate (HR) response to one or more submaximal work rates and to use results to predict VO_2 max (ACSM, 2000). These tests also make several assumptions.

- A steady-state heart rate is obtained for each exercise work rate
- A linear relationship exists between heart rate and work rate
- The maximal heart rate for a given age is uniform
- Mechanical efficiency is the same for everyone

Obviously, various modes of exercise may be used in estimating VO_2 max. A popular protocol used by many exercise physiologists is the YMCA Bike test (Golding, Meyers, and Sinning 1989). Heart rate is measured at two or three 3-min submaximal work loads and extrapolated to the subject's estimated maximal heart rate ($220 - \text{age}$). The measurements from the YMCA bicycle test reflect the cardiorespiratory response (heart rate) of the individual and could theoretically be used to show changes in fitness during a training program. There is a linear relationship between heart rate (HR) and workload (W) (Golding, Meyers, and Sinning 1989). The YMCA protocol requires two HR-workload relationships between 110 and 150 beats per minute (bpm) (Golding, Meyers, and Sinning 1989). To establish a line and estimate VO_2 max, two points are needed and therefore two workloads are used. The line connecting the two measured sub-maximal

HR's is extrapolated to an estimated maximal HR. The VO_2 corresponding to the estimated maximal HR is accepted as the estimated VO_2 max.

There is limited evidence supporting the accuracy of VO_2 max predictions in general. Additionally, there is limited information on the accuracy of the YMCA protocol. Because the accuracy of the YMCA protocol hinges in part on the accuracy of maximal heart rate, the maximal heart rate estimation is critical. Typical formulas for estimating maximal heart rate have considerable error. Maximal heart rate varies substantially among different people of the same age. The standard deviation for 220-age is ± 12 bpm, which means that two thirds of the population varies an average of plus-or-minus 12 heartbeats from the average (Neiman, 2003). Therefore, the present investigation utilized submaximal measures (HR, VO_2) at specific workloads in an attempt to improve the accuracy of the prediction obtained from submaximal YMCA testing. The standard YMCA protocol was completed and then extended to maximal exertion. Sub-maximal measures (HR, VO_2 etc) were used to develop a regression equation predicting VO_2 max. The accuracy of the standard procedure for estimating VO_2 max from the YMCA protocol was compared to the newly developed regression model (using additional sub-maximal measures).

Statement of Problem

The goal of this study was to improve the accuracy of the YMCA cycle ergometer submaximal protocol. By knowing submaximal measures, it can help the accuracy of the testing protocol and the estimation of the individual's aerobic fitness level will improve. In this study, submaximal measures of heart rate, VO_2 and ratings of perceived exertion

were measured while subjects completed the standard YMCA protocol and then continued to maximal exertion.

Significance of the Study

The YMCA cycle ergometer protocol is a popular submaximal test used to estimate an individual's aerobic fitness ($\text{VO}_2 \text{ max}$). Submaximal tests are vital when assessing large and "at risk" populations. They are also convenient when supplies (treadmills) and space are limited. It is extremely important to properly estimate $\text{VO}_2 \text{ max}$ to ensure a proper individualized prescription of exercise intensity.

Hypothesis

The research hypothesis of this investigation was that by utilizing submaximal measures (HR, VO_2) at specific workloads the accuracy of the predicted submaximal YMCA test would be improved. The null hypothesis was that there would be no significant difference in the accuracy of the YMCA protocol after submaximal measures were added to the equation.

Delimitations

This study was limited to the thirty subjects who were all residents of the Western Kentucky area. This investigation is also limited to the age and gender of the participants. All subjects were college aged females. This age category and specific gender limits application of results to this group. Elderly individuals or males cannot necessarily utilize the results.

Limitations

Several aspects of this study could potentially limit its validity. These aspects include but are not limited to the following:

1. The researchers cannot ensure that each subject gave her full effort.
2. The researchers cannot ensure the accuracy of the metabolic cart.

Assumptions

It was the assumption of the researchers involved in this study that the potential obstacles mentioned in the limitations section would not pose a major threat to the validity and reliability of the results.

Definition of Terms

1. VO₂ max- the greatest rate of oxygen uptake by the body measured during severe dynamic exercise and is usually measured during cycle ergometer or treadmill exercise
2. Maximal tests- exercising to the point of volitional exhaustion
3. Submaximal tests- exercising in a less strenuous way resulting in less discomfort and pain
4. Body Mass Index (BMI)- calculation of body weight and height indices for determining degree of obesity (kg / m^2)
5. Skinfold measurements- the most widely used method for estimating percent fat: calipers were used to measure the thickness of a double fold of skin at various sites

6. Physical fitness- a dynamic state of energy and vitality that enables one to carry out daily tasks, to engage in active leisure-time persistently, and to meet unforeseen emergencies without undue fatigue

Chapter 2

Review of Related Literature

History

America experienced an increase in industrialization and urbanization throughout the mid- to late 1800's. During this time, the health of Americans became a greater concern. In response to changes in conditions and in the type of work and travel habits in which people participated and the virtual elimination of infectious diseases, America's first health and fitness reform movement took shape (Nieman, 2003). This reform movement was aimed at the increasingly poor health of the general population, especially in larger cities. Because of this problem, various organizations such as the YMCA and YWCA opened, along with personally-owned gymnasiums. Soon after this reform, medical doctors were hired in collegiate schools to inform and teach students the importance of health and fitness using weight lifting, gymnastics and anthropometric measures (Nieman, 2003). Gradually, schools shifted from medical doctors to physical educators who promoted games and sports as the best way to develop intellectual awareness and enhance social behavior and physical fitness. This change was the beginning of many movements that would come about and served as an opening for sports, intramurals, health clubs and personal fitness opportunities.

Fitness

There appears to be no universally accepted definition of fitness. Over 50 years ago a physician by the name of Steinhaus (Maud and Foster, 1995), evidently viewing fitness from the perspective of the physiologist, defined it as distance from death, a description shared with physicians, who often deem physical fitness as absence of disease. The

definition of fitness in *Mosby's Medical and Nursing Dictionary* (1986) provides a more appropriate and universal definition. It defines fitness as “the ability to carry out daily tasks with alertness and vigor, without undue fatigue, and with enough reserve to meet emergencies or to enjoy leisure time pursuits.”

The cornerstone of a comprehensive physical fitness program is aerobic exercise. Cardiorespiratory endurance or aerobic fitness is defined as the ability to continue or persist in strenuous tasks involving large muscle groups for extended periods of time (Nieman, 2003). The American College of Sports Medicine (ACSM, 2000) considers cardiorespiratory fitness a health related component of fitness because low levels of cardiorespiratory fitness have been associated with increased risk of premature death specifically from cardiovascular and other chronic diseases. Also, the ACSM (2000) states that high levels of cardiorespiratory fitness are associated with higher levels of habitual physical activity, which are in turn associated with many health benefits. There are four parameters of aerobic fitness: aerobic power, also known as maximal oxygen uptake ($\text{VO}_2 \text{ max}$); work efficiency; time constraint for VO_2 kinetics; and the lactate threshold (Maud and Foster, 1995). A central focus of the current investigation is $\text{VO}_2 \text{ max}$.

One of the best ways to measure aerobic fitness is by assessing $\text{VO}_2 \text{ max}$. $\text{VO}_2 \text{ max}$ is an important parameter of human fitness as it represents the upper limit of aerobic exercise tolerance (Maud and Foster, 1995). It is defined as the greatest rate of oxygen uptake by the body measured during severe dynamic exercise and is usually measured during cycle ergometer or treadmill exercise (Powers and Howley, 2004). All endurance activities are performed at some fraction of $\text{VO}_2 \text{ max}$; thus if $\text{VO}_2 \text{ max}$ is abnormally

low, the level of endurance performance is necessarily constrained. After VO_2 max is determined, a percentage of max can be used to determine the level of intensity that should be maintained during exercise. Exercise prescriptions are designed to enhance physical fitness, promote health and ensure safety during exercise. Specific outcomes identified for a particular individual should be the ultimate target. Frequency, intensity, and time must be addressed and understood by each individual if an exercise prescription is to be effective. These are known as the F.I.T. criteria of cardiorespiratory endurance training.

F.I.T. Criteria

The frequency of exercise refers to the number of exercise sessions per week in the program. To improve aerobic fitness, exercise should occur at least three times weekly with no more than two days between workouts (Nieman, 2003, ACSM, 2000).

Intensity is also important when prescribing exercise. Several methods can be used to prescribe intensity including HR. The maximum heart rate represents the maximum attainable HR at the point of exhaustion from all-out exertion (Nieman, 2003).

Depending upon the individual's fitness level, the intensity range will vary according to the HR. For healthy adults to develop and maintain aerobic fitness, the ACSM (2000) recommends the intensity of exercise should be between 55-90% maximal HR or 50-85% of maximum oxygen uptake reserve (Nieman, 2003 and ACSM, 2000). Maximum oxygen uptake reserve is calculated from the difference between resting and maximum VO_2 . To estimate a training intensity, a percentage is added to the resting VO_2 and is expressed as a percentage of VO_2 reserve. Those individuals whose fitness levels are low

may demonstrate an increase in cardiorespiratory fitness with intensities only at 55-64% maximal HR (ACSM, 2000).

Percentages of maximal HR may be used to establish exercise intensity. The actual measured maximal HR is preferable. However, other options are available without knowing the actual measured maximal HR. Two alternative methods are a) calculating a percentage of the estimated HRmax and b) calculating HR reserve, which is also based on HRmax. The target HR range, however, is only a guideline. Some individuals will prefer to exercise at the low end of the target HR range and focus on longer duration.

Time or duration is the last part of the F.I. T. acronym. Time of exercise refers to the duration of time in minutes that the proper intensity level is maintained (Nieman, 2003). The ACSM (2000) recommends 15-20 minutes of exercise progressing to 45-60 minutes. Duration is dependent upon the intensity of the activity; thus lower-intensity activity should be conducted over a longer period of time (30 minutes or more). Conversely, individuals training at higher intensities can benefit from sessions 20 minutes or less (Nieman, 2003). For health benefits, the ACSM (2000) recommends that an individuals participate in 30 minutes or more of moderate-intensity physical activity daily. Regardless of the method, the exercise prescription will primarily depend on an accurate assessment of current fitness (i.e. VO_2 max).

Assessing Fitness

Fitness assessment can be viewed in different ways. Some of the earliest tests used to evaluate fitness were anthropometric measurements. The tests then progressed to include evaluations of muscular strength, endurance, power and eventually included the evaluation of cardiovascular or aerobic fitness. One of the first tests of cardiovascular

fitness dates back to the 20th century. It compared heart rate and systolic blood pressure responses between the horizontal and the standing position (Crampton, 1913). It was believed that an individual who was in better shape would exhibit a maximal rise in blood pressure with no change in heart rate. A test described in 1919, the Barach Cardio-Vascular Test, also used both blood pressure and heart rate to evaluate aerobic fitness (Barach, 1919). The test claimed to reflect the energy demands of the circulatory system. Barach (1919) obtained this information by adding systolic and diastolic pressures then multiplying by resting heart rate to assess fitness.

Another early test that was used to investigate the heart rates response to exercise and recovery was Foster Cardio-Vascular Test (Foster, 1914). The exercise component consisted of stepping up and down from the floor to a step bench for 30 seconds at a rate of 180 steps per minute. During this time, heart rate was measured manually for a five second period. The test, however, lacked validity because of the lack of standardization of the stepping exercise and the potential for error in measurement of heart rate (Maud and Foster, 1995). A more recent test that measured aerobic fitness was the Harvard Step Test (Brouha, 1943). Though this test is still used in various settings, alternative modalities have replaced the popularity of stepping, including cycle and treadmill ergometry. The majority of the earlier fitness tests were crude and in need of revisions. Since the mid 1900's, advances in these fitness tests have been made to better measure and estimate aerobic fitness levels. The Siconolfi (1982) cycle ergometer test yielded strong positive correlations for men ($r = 0.86$) and women ($r = 0.97$) between estimated and measured VO_2 max. The single-stage submaximal treadmill walking test yielded a

correlation between the observed and estimated VO_2 max of $r = 0.96$ (Ebbeling et al., 1991).

The cycle ergometer is frequently used for maximal testing because it is relatively inexpensive compared to a treadmill. It can be portable, requires little space, and provides for stable ECG and blood pressure monitoring. Typically VO_2 max on cycle ergometers are lower than treadmill tests due to involvement of a smaller muscle mass (Maud and Foster, 1995).

Maximal Tests

Direct measurement of oxygen consumption during a maximal exercise test provides the most accurate assessment of aerobic power (Maud and Foster, 1995). Directly measuring VO_2 max, however, requires sophisticated equipment and trained staff. Also, direct measurement is not practical in many situations due to the expense, time required and risks associated with maximal exercise. Maximal tests require subjects to exercise to the point of volitional exhaustion and may require a physician to be present. However, maximal exercise with direct measures of VO_2 permits more accurate determination of VO_2 max compared to estimations from sub-maximal protocols. This accuracy results in a better foundation for prescribing exercise intensity.

In order for subjects to participate in a maximal exercise test, they should first go through a series of screening procedures and be cleared using such professional guidelines as the American College of Sports Medicine (ACSM 2000). The ACSM guidelines use signs and symptoms as well as the following risk factors for stratification of individuals:

- Family history of Heart Disease. Heart Complications in father or male first degree relative before age 55 or before 65 in female first-degree relative.
- Current smoker or quit less than 6 months ago
- Hypertension. Resting systolic blood pressure ≥ 140 or diastolic ≥ 90 or currently taking medication for high blood pressure.
- High cholesterol. Total cholesterol > 200 or HDL < 35 or currently taking medication to lower cholesterol. (If LDL is known use > 130)
- Diabetes or impaired fasting glucose. Fasting glucose ≥ 110 .
- Obesity. BMI ≥ 30 kg/m² or waist > 100 cm (39 inches).
- Sedentary lifestyle. Not participating in regular exercise program.

In order for a subject to be stratified “low risk” according to the ACSM, they must be younger individuals (males < 45 , females < 55) who are asymptomatic and meet no more than one risk factor threshold. While these and other professional guidelines are established to help ensure safety of testing, they can act as a barrier for conducting maximal exercise tests to determine VO_2 max in certain populations.

Maximum oxygen uptake can be estimated from performance on standardized protocols on the treadmill, cycle ergometer or arm ergometer. The protocol chosen most often depends on the mode of equipment that is available, the population being tested and the overall purpose of the test.

Submaximal Tests

Although maximal tests are more accurate when determining VO_2 max, submaximal tests are more practical for estimating or categorizing aerobic capacity in various situations. These situations include testing individuals of an older population

(males ≥ 45 and females ≥ 55), testing large populations, or when equipment or time is limited. When direct measurement of VO_2 max is not feasible, a number of submaximal exercise tests are available to estimate VO_2 max. These tests have been validated by examining a) the correlation between directly measured VO_2 max and the VO_2 max estimated from physiologic responses to submaximal exercise; or b) the correlation between directly measured VO_2 max and test performance (ACSM, 2000).

The decision to use a maximal test or a submaximal test depends largely on the reasons for the test, the risk level of the subject to be tested, and the availability of appropriate equipment and trained personnel. The basic aim of submaximal exercise testing is to determine the HR response to one or more submaximal work rates and the results to predict VO_2 max (ACSM, 2000). These tests also make several assumptions and are as follows:

- A steady-state heart rate is obtained for each exercise work rate
- A linear relationship exists between heart rate and work rate
- The maximal heart rate for a given age is uniform
- Mechanical efficiency is the same for everyone

Of these assumptions, some are easily accepted. However, others such as age-based maximal HR estimation may cause unknown errors in the estimation of VO_2 max.

Although maximal testing provides a more accurate determination of VO_2 max, submaximal exercise testing provides an individual's fitness assessment at a lower cost and reduced risk, and requires less time and effort on the part of the subject (ACSM, 2000).

Modes of Testing

When predicting VO_2 max from responses to submaximal exercise, a variety of modes can be used. Field tests, submaximal treadmill and cycle ergometer tests, and step tests can all be used as modes of testing to predict VO_2 max. Test mode (cycle, treadmill, or step) should be consistent with the primary activity used by the participant to address specificity of training issues.

The primary mode of submaximal exercise testing is traditionally the cycle ergometer (ACSM, 2000). Both single stage and multistage submaximal tests are available to estimate VO_2 max from simple heart rate measurements. In contrast to the single-stage test, Maritz et al. (1961) measured HR at a series of submaximal work rates and extrapolated the response to the subject's age-predicted maximal HR. This method has become one of the most popular assessment techniques to estimate VO_2 max. Another example of this form of exercise test is the YMCA test.

The YMCA protocol uses multiple, three minute stages of continuous exercise (Appendix C). The test is designed to raise the steady-state HR of the subject to between 110 beats/min and 150 beats/min for at least two consecutive stages. It is important to remember that two consecutive HR measurements must be obtained with this HR range to predict VO_2 max. In the YMCA protocol, each work rate is performed for three minutes, and heart rates are recorded during the final 15-30 seconds of the second and third minutes. If the heart rates are not within six beats/min, that work rate is continued for an additional minute. The heart rate measured during the last minute of each stage is plotted against work rate. The line generated from the plotted points is then extrapolated to the age-predicted maximal HR, and a perpendicular line is dropped to the x-axis to

estimate the work rate that would have been achieved if the person had achieved his/her age-predicted maximal HR. A VO_2 corresponding to the predicted maximal work rate is identified and accepted as the $\text{VO}_{2\text{max}}$ (Appendix D).

Accuracy of Submaximal Tests

The submaximal cycle ergometer tests, particularly the YMCA protocol, have the advantage of utilizing portable, inexpensive equipment. A major disadvantage of the cycle ergometer is that the majority of Americans are not accustomed to cycling. Also, because the accuracy of the YMCA protocol is based on the measurement of HR at one or more work loads, the protocol and other submaximal protocols have several limitations. First, for any given rate of submaximal work, HR can vary independently of VO_2 due to emotional state and degree of excitement. Heart rate can also vary with elapsed time after the previous meal, total circulating hemoglobin, degree of hydration, and ambient temperature (Maud and Foster, 1995).

A second limitation involves the assumption that HR is a linear function of VO_2 throughout the range of work rates up to maximum. In the previously mentioned study, however, Maritz (1961) showed that HR reaches its maximum value at a slightly lower work rate than VO_2 . This asymptotic relationship between HR and VO_2 causes a slight underestimation of $\text{VO}_{2\text{max}}$ (Maud and Foster, 1995). Third, the variation in maximal HR with age is approximately 5% (Maud and Foster, 1995). Therefore, if the HR max is estimated at 200 beats/min, it is actually between 180 to 200 beats/min. A VO_2 max for an individual with a true maximum HR of 180 beats/min will be overestimated and a true maximum HR of 220 beats/min will be underestimated. In all estimations, VO_2 max can be influenced by a suggested error of 15% (Neiman, 2003). The problem with a 15%

error is that it could possibly yield a) an incorrect fitness classification, and/or b) an inappropriate intensity range.

As discussed, maximal oxygen uptake provides the best criterion measure for aerobic fitness and prescription of exercise intensity in programs designed to enhance cardiorespiratory fitness. Because maximal tests require subjects to exercise to the point of volitional exhaustion and may require a physician to be present, this form of testing increases risks of injury related problems and could also exclude certain high risk individuals from participating. Therefore, submaximal exercise tests offer alternative ways to predict maximal VO_2 . There is limited information on the accuracy of the more popular YMCA protocol. Therefore, the present investigation focused on utilizing submaximal measures (HR, VO_2) at specific workloads in an attempt improve the accuracy of the prediction that can be obtained from submaximal testing.

Chapter 3

Methodology

Subjects

Upon approval by the Human Subjects Review Board (HSRB), thirty ($n = 30$) college-age females (20.8 ± 1.4 years) with an average height of 165.9 ± 6.0 cm and average weight of 63.3 ± 8.5 kg volunteered for the study. Subjects were recruited from various Western Kentucky University Physical Education classes. The subjects had an average Body Mass Index (BMI) of 23.1 ± 3.2 and Body fat percent of 23.9 ± 4.1 . Each subject indicated her activity level (4.8 ± 1.5) using a University of Houston numerical Physical Activity Level rating scale ranging from a scale from 0-7, zero being least active and seven being most active (Jackson et. al, 1990) (Appendix C).

Screening

Each individual, prior to testing, was required to read and complete the Physical Activity Readiness Questionnaire (PAR-Q) (Appendix B) and a Health Status Questionnaire (Appendix B). These documents helped to ensure each subject's safety in participation, and eliminated those at an increased risk for participation in vigorous exercise.

Descriptive Data

Before exercise testing, all resting measurements were collected. Body fat percentage was estimated using Lange (Cambridge, MD) skinfold calipers and a three site method (Triceps, Iliac crest, and Thigh) (ACSM, 2000). Using the subject's age and sum of three skinfold measures, body fat percentage was estimated from a chart (Maud and Foster, 1995). Body Composition was also estimated using hand held Bioelectric

Impedance Analysis (Omron Healthcare, Inc. Illinois). The subject's height (cm) and weight (kg) were recorded (no footwear).

Testing Protocol

The YMCA Submaximal cycle ergometer protocol (Golding, Meyers, and Sinning 1989) was completed by all subjects following exact procedures outlined in the *Y's Way to Physical Fitness*, third edition (1989). On the day of testing, the subjects were asked to abstain from any physical exertion and from eating for two hours prior to the test. Seat height was appropriately set for each individual on a Monark cycle Ergometer (Varberg, Sweden). Handlebars were adjusted for individual preference. Subjects were fitted with an appropriately-sized air-cushioned face-mask (Vacu-med, Ventura, CA, USA) and a Polar heart rate (HR) monitor transmitter (Stamford, CT, USA) at the level of the sternum. The bicycle cadence was maintained at 50 rpm using a digital cyclocomputer.

The initial workload was set at 150 kpm/min (Appendix C). The subjects cycled at the first workload for three minutes. The HR was recorded during the final 15-30 seconds of each minute. Ratings of Perceived Exertion (Appendix C) were also requested and recorded at the end of each minute. All workloads were determined according to the guide in the *Y's Way to Physical Fitness: The complete guide to fitness testing and instruction*, 3rd edition (1989). A copy of the protocol is presented in Appendix C. If the difference in HR's in the second and third minutes were greater than 6 beats/min, the stage was extended for an extra minute to obtain a stable HR. Using HR range of 110-150 beats/min, the HR-WK relationship may then be plotted to estimate VO_2 max (Appendix D).

Following the completion of the YMCA protocol, subjects continued to cycle with increases of 0.5kp resistance per minute until subjects reached volitional exhaustion. Criteria for achievement of VO_2 max according to the text by Maud and Foster (1995) were used. They were: 1) Plateau in VO_2 as work rate was increased, 2) Respiratory Exchange Ratio (RER) at test termination greater than 1.00, 3) HR at test termination greater than 85% of age-predicted max ($220 - \text{age}$). Metabolic data (VO_2 , VCO_2 , respiratory exchange ratio, ventilation, V_E/VO_2 , V_E/VCO_2) were collected using a Vacu·med Vista mini-cpx (silver) metabolic measurement system (Vacu·med, Ventura, CA, USA), calibrated prior to each test with a gas of known composition. Turbofit software (Vacu·med, Ventura, CA, USA) designed for use with the metabolic system was set to report mean metabolic data over 20 sec time periods for determination of VO_2 max. Because the application of the current equation would require an estimation of maximal HR, the formula $220 - \text{age}$ was used to estimate maximal HR.

Design and Analysis

Estimations from the standard YMCA protocol and the Houston non-exercise prediction were compared to each other and actual VO_2 max using t-tests. Multiple regression analyses were performed using SPSS for Windows 2004 to generate regression equations to enhance the accuracy of VO_2 max estimations from the YMCA sub-maximal cycling protocol.

Chapter 4

Presentation of Results and Analyses

T-tests

A significant difference ($p = .015$) was found between the Measured VO_2 max (MVO_2) (Mean = $36.98 \text{ ml/kg/min} \pm 5.1$) and VO_2 max estimated from the YMCA protocol (YVO_2) (Mean = $34.80 \text{ ml/kg/min} \pm 6.3$). The paired samples correlation was $r = 0.696$ ($p = .000$). Also there was a significant difference ($p = .003$) between VO_2 max estimated from the Houston non-exercise test (HVO_2) (Mean = $38.97 \text{ ml/kg/min} \pm 3.4$) and MVO_2 . The paired samples correlation was $r = .762$ ($p = .000$).

Regression Analysis

A multiple linear regression using twenty-five randomly selected subjects showed the ability of the YMCA prediction to improve by incorporating a regression model. The YMCA prediction improved from $r = .696$ to $r = .817$ when BMI was entered into the equation and $r = .822$ when skinfold was entered into the equation. Using BMI and Skinfolds in an equation increased the r -value versus solely using graphic plots of steady state HR responses at protocol-determined workloads to estimate VO_2 max. Model summaries are indicated in Table 1 (Appendix D).

Cross-validation

The remaining five subjects were used for cross-validation of the regression model. The paired sample T-test showed there was a significant difference ($p = .031$) between MVO_2 (Mean = $37.9 \text{ ml/kg/min} \pm 3.4$) and YVO_2 (Mean = $32.1 \text{ ml/kg/min} \pm 6$) for the remaining five subjects. There was no significant difference ($p = .472$) between MVO_2 (Mean = $37.9 \text{ ml/kg/min} \pm 3.4$) and VO_2 predicted from regression Model 1 (Mean = 36.5

ml/kg/min ± 2.8) which used body fat percent estimated from a three-site skinfold sum.

Also, there was no significant difference ($p = .321$) between MVO_2 and regression Model 2 (Mean = 35.9 ml/kg/min ± 3.3) which utilized BMI.

Discussion of Results

The researcher examined the utilization of submaximal measures (HR, VO_2) at specific workloads in an attempt to improve the accuracy of the prediction that can be obtained from submaximal testing. The standard YMCA protocol was completed and then extended to maximal exertion. Submaximal measures (HR, VO_2) were considered for utilization in developing a regression equation predicting VO_2 max. This regression equation was compared to the accuracy of the standard procedure for estimating VO_2 max from the YMCA protocol. Upon completion of the maximal tests, no significant difference was found between the YMCA protocol and the new regression equation. Therefore, because submaximal measures (HR, VO_2) could not be utilized to improve the accuracy of the prediction of the YMCA protocol, the original purpose was de-emphasized and redirected. Considering the apparent utility of anthropometric measures in estimating VO_2 max, the researcher sought to improve the accuracy of the YMCA protocol by adding anthropometric measures (BMI, Skinfolds) to a regression model.

After completing all maximal tests, statistics showed there was a significant difference ($p = .015$) between MVO_2 (Mean = 36.98 ml/kg/min ± 5.1) and YVO_2 (Mean = 34.80 ml/kg/min ± 6.3). The paired samples correlation was $r = 0.696$ ($p = .000$). Although a significant correlation resulted ($r = .696$) it was not as strong a correlation as other submaximal estimations (Houston non-exercise test $r = .81$, Queens College step test $r = .92$). Additionally, it was not a strong predictor because of a significant

difference between the means. Statistics also revealed that there was a significant difference ($p = .003$) between the Houston non-exercise test (Mean = 38.97 ml/kg/min) and MVO_2 (Mean = 36.98 ml/kg/min). The paired samples correlation was $r = .762$ ($p = .000$).

Anthropometric measures (BMI, Skinfolts) were chosen to improve the YMCA estimations for different reasons. As physical activity increases, a decrease in BMI and body fat percent will occur. Additionally, with an increase in physical activity, aerobic capacity increases. Therefore, knowing BMI or body fat percent partially reflects the level of aerobic activity and consequently VO_2 max. For example, it is unlikely to find an obese person with a high VO_2 max.

Another reason for choosing anthropometric measures was the success of the Houston non-exercise test (Jackson et. al, 1990) and the easy availability of the measures that can be collected during any fitness test. When using the Houston non-exercise test, gender specific equations require subjects to enter personal data (age, physical activity, BMI, percent body fat) to predict VO_2 max. When using BMI in the Houston equation, the r -value = 0.81, and when using percent body fat, the r -value = 0.78. When comparing the r -values for submaximal protocols and the non-exercise equation, it appears that VO_2 max can be predicted without having submaximal test data almost as accurately as with a submaximal test data. It is therefore plausible that incorporating such measures in a regression model based on VO_2 max estimated from the YMCA protocol would improve the utility of this test.

Using BMI and Skinfolts in an equation increased the r -value of the YMCA protocol versus solely using graphic plots of steady state HR responses at protocol-

determined workloads ($r = 0.696$). Model One added skinfold percentages to the YVO_2 equation and improved the accuracy of the YMCA estimation to $r = 0.822$. Model Two with the addition of BMI improved the YMCA estimation to $r = 0.817$. These values are similar to other protocols with the addition of simple, non-invasive data.

Cross-validation of the regression model was used on the remaining five subjects. Results of the paired sample T-test showed there was a significant difference ($p = 0.031$) between MVO_2 ($37.9 \text{ ml/kg/min} \pm 3.4$) and YVO_2 ($32.1 \text{ ml/kg/min} \pm 6$). However, there was no significant difference ($p = 0.472$) between MVO_2 and VO_2 predicted from regression Model One ($36.5 \text{ ml/kg/min} \pm 2.8$). Also, there was no significant difference ($p = 0.321$) between MVO_2 and regression Model Two ($35.9 \text{ ml/kg/min} \pm 3.3$). Although results showed there was no significant difference from the actual measured VO_2 and the estimated VO_2 measured from Models One and Two, the accuracy of the YMCA protocol was enhanced. Therefore, by adding anthropometric measures (BMI and skinfolds) to the popular YMCA submaximal cycle ergometer protocol, it can better estimate a subject's VO_2 max compared to solely using graphic plots of steady state HR responses at a given workload. It should be noted, however, that even though the R value after adding anthropometric measures to the YMCA protocol increases its accuracy, not testing someone at all and using the Houston non-exercise test produces similar correlations.

Maximal HR Error

Because the YMCA protocol was significantly different from the actual measured VO_2 , and because the YMCA solely uses graphic plots of steady state HR responses at protocol-determined workloads, the accuracy of the estimated HR max was questioned. The YMCA protocol uses $220 - \text{age}$ to estimate max HR along with protocol-determined

workloads to establish the estimated VO_2 max. Upon completion of the maximal test, one variable that was obtained during testing was the actual measured HR max. In having this information, it was thought that the actual measured HR would improve the accuracy of the YMCA estimation of VO_2 max.

Statistical results from all subjects ($n = 30$) showed a significant difference ($p = 0.000$) between actual HR max (Mean = $184.3 \text{ bpm} \pm 8.4$) and estimated HR max ($199.2 \text{ bpm} \pm 1.4$). The paired samples correlation was $r = -0.032$ ($p = 0.866$). This shows that the actual HR max would have predicted worse than the estimated HR max (220-age) (Appendix D). Therefore, the YMCA protocol predicts VO_2 max better when using the 220-age estimated HR max. There was a consistent under prediction of VO_2 max using estimated max HR. If the actual measured HR max had been used it would have significantly under-predicted the estimated VO_2 max even more, further impairing the accuracy of the YMCA test.

A common HR estimation for females is 225-age. Compared to actual HR max (Mean = $184.3 \text{ bpm} \pm 8.4$), statistics showed the female HR max estimation (Mean = $204.2 \text{ bpm} \pm 1.4$) was significantly different ($p = 0.000$). The paired samples correlation was $r = -0.032$ ($p = 0.000$).

Chapter 5

Summary of Study

Research shows that various submaximal protocols provide moderately accurate measures of estimated VO_2 max (Jackson et al., 1990, Kline et al., 1987, McArdle et al., 1972, Siconolfi et al., 1985). For example, the Harvard step test, the single-stage treadmill walking test, and the one-mile walk test-- possibly because of the familiarization of walking that occurs in everyday routines-- provide high correlations with actual VO_2 maximal measurements. Besides step tests and walk tests, the Houston non-exercise test provides a high correlation with the actual measured VO_2 max. The gender specific equations require subjects to enter personal data (age, physical activity status and percent body fat or BMI) to predict VO_2 max. When r-values are compared for submaximal protocols and the non-exercise test, it appears that VO_2 max can be predicted without having submaximal test data almost as accurately as with submaximal test data. More than one factor influencing VO_2 max appears to be the physical activity level of the individual as well as anthropometric measures potentially altered by improved fitness.

Future Research

The results of this study show that the YMCA cycle ergometer submaximal protocol can be improved with the addition of both body fat percentage or BMI. Because the YMCA protocol is so popular, more research should be conducted to improve its accuracy.

APPENDICES

APPENDIX A
APPROVAL LETTER FROM
HUMAN SUBJECTS REVIEW BOARD

Based on the findings of this study, the following recommendations regarding future research are made:

1. Providing gender specific equations could provide a better estimation for both males and females.
2. The addition of Physical Activity Level to the YMCA protocol could aid in the improvement of the accuracy of the estimated VO_2 max.

WESTERN KENTUCKY UNIVERSITY
Human Subjects Review Board
Office of Sponsored Programs
104 Foundation Building
270-745-4652; Fax 270-745-4211
E-mail: Stevea.Kaufkins@wku.edu

In future correspondence please refer to HS04-063, February 24, 2004

Lindsay Parson
Physical Education
Smith Stadium

Dear Lindsay:

Your research project, "Estimation of maximal oxygen consumption (VO2 max) using sub-maximal heart rate and sub-maximal VO2," was reviewed by the HSRB and it has been determined that risks to subjects are: (1) minimized and reasonable; and that (2) research procedures are consistent with a sound research design and do not expose the subjects to unnecessary risk. Reviewers determined that: (1) benefits to subjects are considered along with the importance of the topic and that outcomes are reasonable; (2) selection of subjects is equitable; and (3) the purposes of the research and the research setting is amenable to subjects' welfare and producing desired outcomes; that indications of coercion or prejudice are absent, and that participation is clearly voluntary.

1. In addition, the IRB found that: (1) signed informed consent will be obtained from all subjects. (2) Provision is made for collecting, using and storing data in a manner that protects the safety and privacy of the subjects and the confidentiality of the data. (3) Appropriate safeguards are included to protect the rights and welfare of the subjects.

a. Your research therefore meets the criteria of Full Board Review and is Approved.

2. Please note that the institution is not responsible for any actions regarding this protocol before approval. If you expand the project at a later date to use other instruments please re-apply. Copies of your request for human subjects review, your application, and this approval, are maintained in the Office of Sponsored Programs at the above address. Please report any changes to this approved protocol to this office. A Continuing Review protocol will be sent to you in the future to determine the status of the project.

Sincerely,



Ms. Stevea Kaufkins
Compliance Specialist

cc: Human Subjects File HS04-063
cc: Dr. Matt Green

APPENDIX B
SCREENING TOOLS

Informed Consent Statement

The Use of Submaximal Measures of Oxygen Consumption and Heart Rate for the Estimation of VO₂max using Regressional Analysis

The purpose of this research project is to utilize measurements of submaximal oxygen consumption and heart rate (HR) in order to estimate maximal oxygen consumption using regressive analysis from the YMCA cycle ergometer protocol.

Requirements

***ALL SUBJECTS MUST BE 18 YEARS OR OLDER!!**

As a volunteer in this research project you will be asked to do the following:

1. Complete all necessary forms including this consent form and a form measuring your current health
2. Submit to collection of descriptive data
 - a. Age, height, weight,
 - b. Body fat percent – this will be measured by pinching your skin at 3 locations (males: chest, stomach, upper leg, or females: upper arm, side of the waist, upper leg)
3. Perform 1 maximal exertion bike test

YOU SHOULD NOT PARTICIPATE IF YOU:

- 1– ARE PREGNANT OR MIGHT BE PREGNANT
- 2– YOU ARE TAKING DRUGS (PRESCRIPTION OR ANY OTHER)
- 3– HAVE A FAMILY HISTORY OF HEART, VASCULAR, OR KIDNEY DISEASE.

Only 1 visit to the lab is required. Following consent forms, health screening, and descriptive data you will complete the maximal exertion treadmill test:

~~*Maximal Exertion Bike Session~~ During this trial you will exercise on a mechanically braked cycle ergometer for approximately 15-20 minutes depending on your current fitness level. The intensity will be very easy at the beginning of the test. However, every 3 minutes the pedal cadence will be increased to make the exercise more difficult. When you feel you can no longer continue at the required cadence the test will be stopped and you will be monitored during a low intensity cool-down. The test may also be stopped when testers feel it is not safe for you to continue.

*Maximal refers to the most intense exercise you are capable of performing

While you are exercising on the bike you will be required to wear a breathing mask. It will cover your nose and mouth but will permit you to freely breathe room air. You will also be required to wear a heart rate monitor around your chest near the area of your sternum (breastbone). The monitor resembles a small belt. During all exercise session you will also be asked to provide a numerical rating of how difficult the exercise feels. During the test you will experience severe fatigue particularly near the completion of the test. Also, you should expect to experience increased respiratory rate, increased heart rate, possible lightheadedness, and other uncomfortable symptoms associated with very intense physical exertion.

Prior to participation you MUST complete the consent and the health status questionnaire. These forms will be used to evaluate the safety of your participation as well as your willingness to participate. Any questions you may have about your participation or the forms you complete are welcomed and will be answered to your satisfaction.

Risks Due to Participation

Potential risks to your health and well-being because of your participation include 1) cardiovascular injury (heart attack or stroke), 2) severe acute fatigue, 3) lightheadedness, dizziness, nausea, 4) all other possible risks associated with intense physical exertion.

*The American College of Sport Medicine (2000) suggests the following regarding the potential for risk/injury as the result of participating in an exercise test of this nature

PAR - Q & YOU

(A Questionnaire for People Aged 15 to 69)

31

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES NO

- | | | |
|--------------------------|--------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|
| <input type="checkbox"/> | <input type="checkbox"/> | 1. Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor? |
| <input type="checkbox"/> | <input type="checkbox"/> | 2. Do you feel pain in your chest when you do physical activity? |
| <input type="checkbox"/> | <input type="checkbox"/> | 3. In the past month, have you had chest pain when you were not doing physical activity? |
| <input type="checkbox"/> | <input type="checkbox"/> | 4. Do you lose your balance because of dizziness or do you ever lose consciousness? |
| <input type="checkbox"/> | <input type="checkbox"/> | 5. Do you have a bone or joint problem that could be made worse by a change in your physical activity? |
| <input type="checkbox"/> | <input type="checkbox"/> | 6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition? |
| <input type="checkbox"/> | <input type="checkbox"/> | 7. Do you know of <u>any other reason</u> why you should not do physical activity? |

YES to one or more questions

If
you
answered

Talk with your doctor by phone or in person **BEFORE** you start becoming much more physically active or **BEFORE** you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want—as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active—begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal—this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively.

DELAY BECOMING MUCH MORE ACTIVE:

- If you are not feeling well because of a temporary illness such as a cold or a fever—wait until you feel better; or
- If you are or may be pregnant—talk to your doctor before you start becoming more active.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

You are encouraged to copy the PAR-Q but only if you use the entire form

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction.

NAME _____

SIGNATURE _____

DATE _____

SIGNATURE OF PARENT _____
or GUARDIAN (for participants under the age of majority)

WITNESS _____



Name _____ Age _____ Gender: male female Date _____

Please mark a response for each item below. If you do not fully understand a question, ask the individual administering the test to clarify.

Section 1:

Mark all the following that pertain to you.

Yes No 1. Family history of Heart Disease. Heart complications in father or male first-degree relative before age 55 or before 65 in female first-degree relative

Yes No 2. Current smoker or quit less than 6 months ago

Yes No 3. Hypertension: Resting systolic blood pressure > 140 or diastolic > 90 or currently taking medication for high blood pressure.

Yes No 4. High cholesterol. Total cholesterol > 200 or HDL < 35 or currently taking medication to lower cholesterol. (If LDL is known use > 130)

Yes No 5. Diabetes or impaired fasting glucose. Fasting glucose > 110

Yes No 6. Obesity. BMI $> 30 \text{ kg/m}^2$ or waist $> 100 \text{ cm}$ (39 inches)

Yes No 7. Sedentary lifestyle. Not participating in regular exercise program.

Section 2:

Do you experience any of the following?

Yes No 1. Pain, discomfort in the chest, neck, jaw, arms, or other areas that may be indicative of a heart problem.

Yes No 2. Shortness of breath at rest or with mild exertion

Yes No 3. Dizziness or faintness

Yes No 4. Labored breathing especially at night

Yes No 5. Swelling, especially at or near the ankles

Yes No 6. Severe pain in the legs during exertion that goes away with rest

Yes No 7. Fluttering of the heart or rapid heart rate for no apparent reason

Yes No 8. Known heart murmur (mitral valve prolapse, etc)

Are there ANY reasons you know of that you should not perform physical activity?

APPENDIX C
DATA COLLECTION SHEETS
AND
RATINGS OF PERCEIVED EXHERTION
AND
PROTOCOL GUIDE

Subject _____ Date _____

Age _____ Height _____ Weight _____

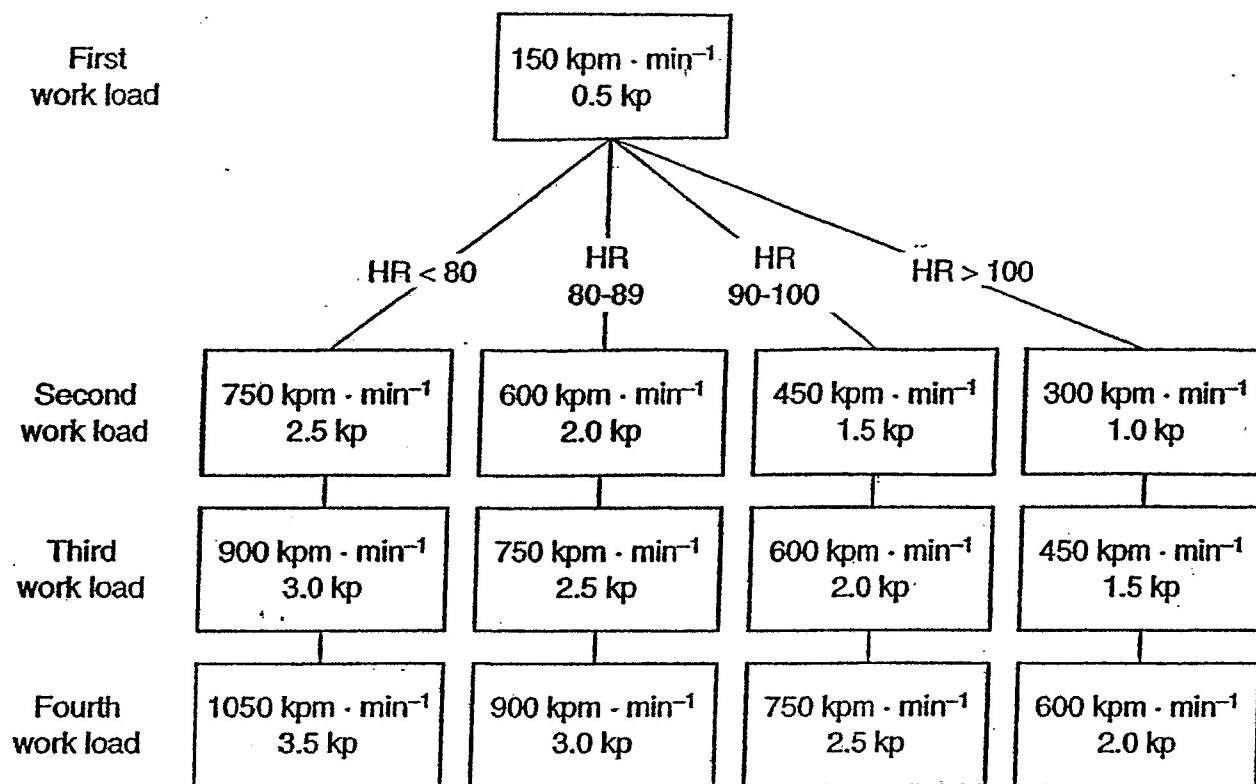
Chest _____ Abdomen _____ Thigh _____

Sum of Skinfolts _____ Estimated Body Fat % _____

Maximal Exertion Bike Test (60 rpms)

Min	KP	HR	VO2	RPE (O, L, C)
0-1	0.5	_____	_____	_____
1-2	0.5	_____	_____	_____
2-3	0.5	_____	_____	_____
3-4	_____	_____	_____	_____
4-5	_____	_____	_____	_____
5-6	_____	_____	_____	_____
6-7	_____	_____	_____	_____
7-8	_____	_____	_____	_____
8-9	_____	_____	_____	_____
9-10	_____	_____	_____	_____
10-11	_____	_____	_____	_____
11-12	_____	_____	_____	_____
12-13	_____	_____	_____	_____
13-14	_____	_____	_____	_____
14-15	_____	_____	_____	_____
15-16	_____	_____	_____	_____
16-17	_____	_____	_____	_____

VO₂ max _____ Peak HR _____ Threshold _____

**Directions:**

1. Set the first work load at 150 kpm · min⁻¹ (0.5 kp).
2. If the HR in the 3rd minute is
 - less than (<) 80, set the second load at 750 kpm · min⁻¹ (2.5 kp);
 - 80 to 89, set the second load at 600 kpm · min⁻¹ (2.0 kp);
 - 90 to 100, set the second load at 450 kpm · min⁻¹ (1.5 kp);
 - greater than (>) 100, set the second load at 300 kpm · min⁻¹ (1.0 kp).
3. Set the third and fourth (if required) loads according to the loads in the boxes below the second loads.

IE 11.4 Guide for setting power outputs (work loads) for men and women on YMCA submaximal cycle meter test.

Adapted from *Y's way to physical fitness: The complete guide to fitness testing and instruction*, 3rd ed., with permission of the American College of Sports Medicine, 101 N. Wacker Dr., Chicago, IL 60606.

Physical Activity Level

Rate your Physical Activity Level (past 6 months – present) on a weekly basis from the list below:

- 0 Avoids walking or exertion (e.g., always uses elevator, drives whenever possible instead of walking).
- 1 Walks for pleasure, routinely uses stairs, occasionally exercises sufficiently to cause heavy breathing or perspiration.
- 2 Participates 10-60 minutes per week in recreation or work requiring modest physical activity (golf, horseback riding, weight lifting, table tennis).
- 3 Participates over one hour per week in recreation or work requiring modest physical activity (golf, horseback riding, weight lifting, table tennis).
- Participates regularly in heavy physical exercise (running, jogging, swimming, cycling) or engages in vigorous aerobic type activity (tennis, basketball):
- 4 Runs less than one mile per week or spends 30 minutes per week in comparable physical activity.
- 5 Runs 1-5 miles per week or spends 30 -60 minutes per week in comparable physical activity.
- 6 Runs 5 – 10 miles per week or spends 1 – 3 hours per week in comparable physical activity.
- 7 Runs over 10 miles per week or spends over 3 hours per week in comparable physical activity.

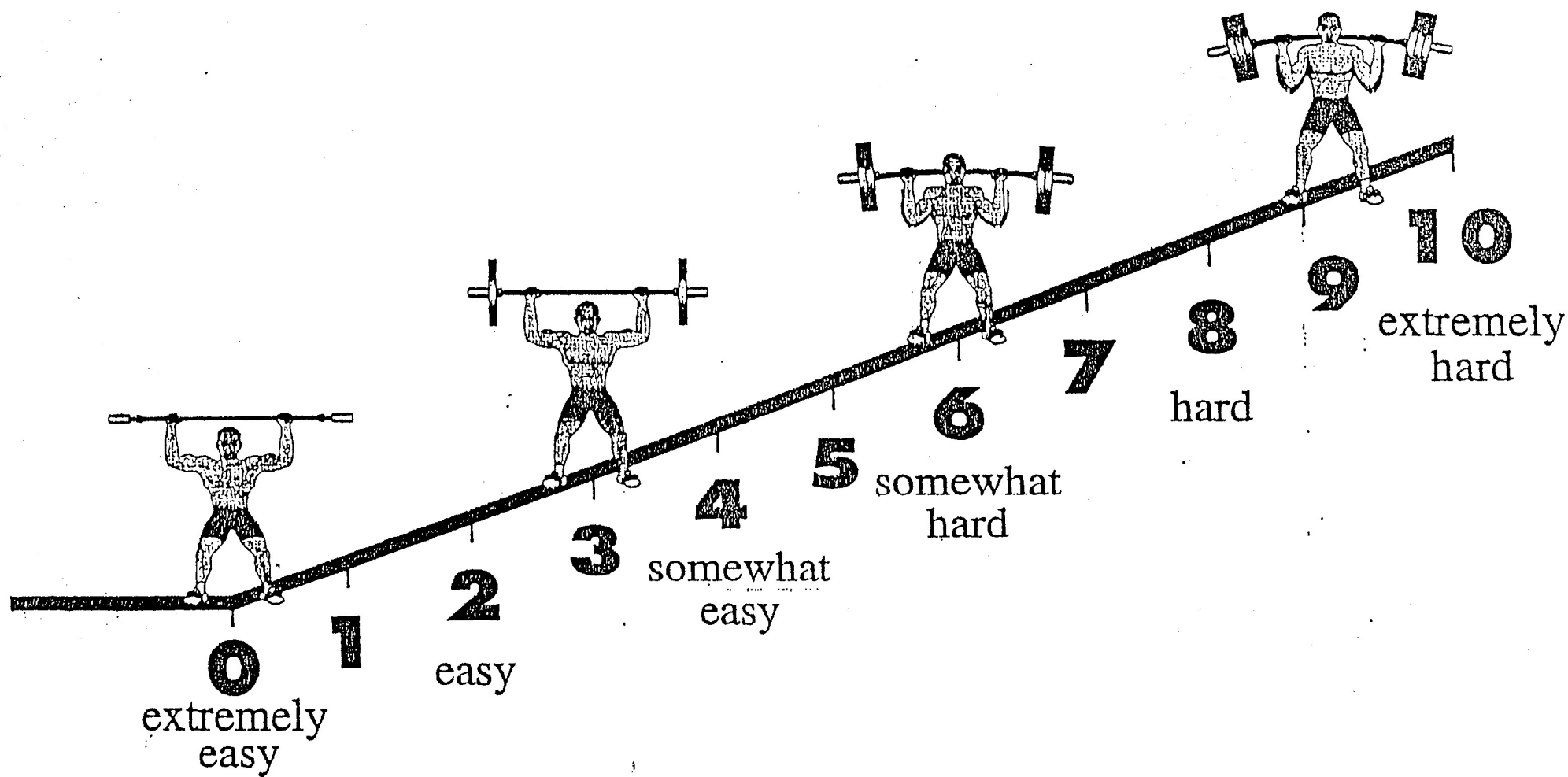


FIGURE 1—OMNI-Resistance Exercise Scale (OMNI-RES) of perceived exertion.

APPENDIX D
GRAPHS AND TABLES

3.14 L/min \rightarrow 49.9
Actual HR may
 189

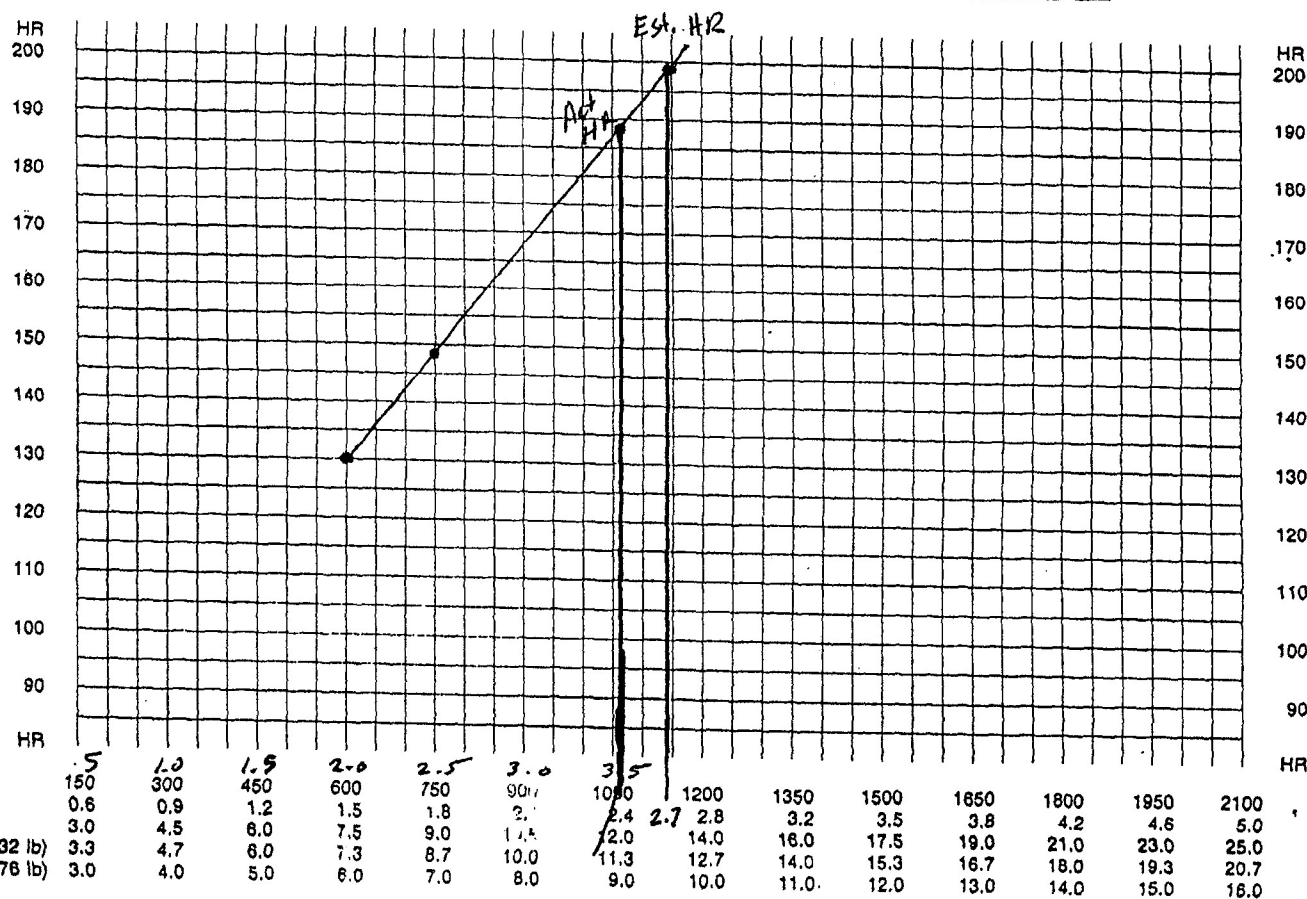
MAXIMUM PHYSICAL WORKING CAPACITY PREDICTION

NAME 900 AGE 21 WEIGHT 140 LB 63 KG SEAT HEIGHT _____

	DATE	1st WORKLOAD HP USED	2nd WORKLOAD HP USED	MAX WORKLOAD	MAX O ₂ (L/min)	MAX O ₂ (mL/kg)
TEST 1	_____	_____	_____	_____	_____	_____
TEST 2	_____	_____	_____	_____	_____	_____
TEST 3	_____	_____	_____	_____	_____	_____

DIRECTIONS

1. Plot the HR of the 2 workloads versus the work (kgm/min).
2. Determine the subject's max HR line by subtracting subject's age from 220 and draw a line across the graph at this value.
3. Draw a line through both points and extend to the max HR line for age.
4. Drop a line from this point to the baseline and read the predicted max workload and O₂ uptake.



55 Max HR:
 99

2.7 L/min \rightarrow 42.8 mL/kg ^{Est}

TABLE 1
Regression Model Summaries

	Coefficients	Coefficient St. Error	Coeff Sig	Model R	Model Sig
<u>Model 1</u>				0.822	0.000
Constant	39.271	8.697	0.000		
Skinfold	-0.024	0.20	0.005		
YVO2	0.356	0.134	0.014		
<u>Model 2</u>				0.817	0.000
Constant	37.443	8.51	0.000		
BMI	-0.709	0.121	0.001		
YVO2	0.446	0.238	0.007		

Model 1: $VO_2 = 39.271 - (0.024 \times \text{Skinfold}) + (0.356 \times YVO_2)$

Model 2: $VO_2 = 37.443 - (0.709 \times \text{BMI}) + (0.446 \times YVO_2)$

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